ORBITAL ANOMALIES IN GODDA339RD SPACECRAFT

FOR

CY 1987

WILLIAM G. ELSEN

AUGUST 1988

ASSURANCE REQUIREMENTS OFFICE

OFFICE OF FLIGHT ASSURANCE

NASA/GODDARD SPACE FLIGHT CENTER

December 30, 1991

TO: Distribution

FROM: 302/Assurance Requirements Office

SUBJECT: Correction to Reports, *Orbital Anomalies in Goddard Spacecraft for CY1987, 1988, 1989 & 1990*

The purpose of this memorandum is to advise recipients of any of the four subject reports that some of the textual information, in the body of the report and Appendix A, concerning the Landsat-5 Ku Band is in error. The Ku Band subsystem in the spacecraft is functioning satisfactorily (presently using the redundant unit) and it is regularly used to send data from the Thematic Mapper (TM) to the ground via the TDRSS.

William G. Elsen

Summary

This report presents a summary of the in-orbit reliability performance of spacecraft built under the management of the Goddard Space Flight Center that were active during calendar year 1987. It is one of a series of such reports that collectively form a continuous published record of this performance. The major feature of these reports is a log of all anomalies occurring during the report period which provides a description of the anomaly and its time of occurrence. Each anomaly is classified according to criticality, type, subsystem, and other relevant criteria. Although some statistical analysis and comparisons are given, the purpose of the report is primarily documentary, with more extensive statistical treatment to be presented elsewhere.

Introduction

Since the earliest days of the Center, attempts have been made to record the performance of Goddard-managed spacecraft. Although statistical summaries exist, until the last decade or so the actual raw data was considered sensitive and was not published. This is unfortunate, since over the years it has been observed that the potential uses for this data are open-ended and cannot be predicted in advance. Hence, any pre-digested data is likely not to be what is needed in many instances.

The first report to contain specific anomaly data was the contractor report Analysis of Spacecraft On-Orbit Anomalies and Lifetimes, PRC R-3579, dated 10 February 1983, which covers roughly the period from 1978 to mid-1982, and includes JPL as well as GSFC spacecraft. This was followed by Orbital Anomalies in Goddard Spacecraft 1982-1983, Orbital Anomalies in Goddard Spacecraft 1984, ... 1985, ... 1986 published by the Office of Flight Assurance. The current report updates the record through 1987.

Spacecraft Activity Schedule

At the beginning of this reporting period, on January 1, 1987, there were a total of 20 GSFC spacecraft in full or partial service. This number includes eight meteorological spacecraft operated by NOAA consisting of three of the TIROS/NOAA series & five of the GOES series; Landsat-4, and Landsat-5.

There was one new spacecraft launched during the year and one old spacecraft ended its orbital life. In February the GOES-7(H) spacecraft was successfully launched on a Delta Launch Vehicle. In September the ISEE-1 spacecraft reentered the atmosphere ending 10 years of successful operations. The complete list of satellites active during all or part of 1987 is as follows:

NASA		NOAA
AMPTE/CCE		NOAA-6
DE-1	O	NOAA-9
ERBS	N	NOAA-10
IMP-8	G	GOES-2
ISEE-1	O	GOES-3
ICE (ISEE-3)	I	GOES-4
IUE	N	GOES-5
Nimbus-7	G	GOES-6
SMM		Landsat-4
TDRS-1		Landsat-5
	NEW	GOES-7

Details are shown in the Spacecraft Lifetime Data in Appendix A, which includes virtually all GSFC launches since 1960, excluding minor GAS (Get Away Specials) experiments and a number of international missions Goddard participated in but is not considered to have had responsibility.

Overall, there were 43 anomalies, distributed over 11 different spacecraft, during the year. This compares with 37 anomalies distributed over 22 spacecraft in the previous year (1986).

In the following sections, each mission and its overall performance is discussed in more detail. A complete log of anomalies appears at the end of the report.

Data Sources

The data reported herein are taken primarily from three sources. For NASA spacecraft, the main source is the Spacecraft Orbital Anomaly Reports (SOAR). For TIROS/NOAA spacecraft the TIROS Orbital Anomaly Reports (TOAR) are used, and the GOES Anomaly Reports (GAR) cover the GOES series. These data bases are maintained by the Assurance Requirements Office, in the case of SOAR, and the Metsat Office in the case of TOAR and GAR. The information contained in these reports is originated in the corresponding spacecraft operations control centers. Supplementary information is obtained through miscellaneous written reports, attendance of the regular meetings of the Orbiting Satellites Project, and other verbal contacts. Additional backup information on many of these anomalies is available through this office. In some cases the classifications are not necessarily based on the judgments of this office, and are subject to revision. This applies particularly to "open" anomalies.

Spacecraft Performance Summary

The following provides a summary of the condition and performance of the active spacecraft covered by this report:

AMPTE/CCE (Active Magnetospheric Particle Tracer Explorers/Charge Composition Explorer)

This spacecraft continued to obtain scientific data through this year. The solar array continued to show evidence of old-age degradation. In May it was noticed that a power negative condition exists when the transmitter is on or the tape recorder is playing back. That is, the battery is required to supplement the array, even in full sun, during these events. In July battery temperatures fell to +5°C causing some concern. This was partly a seasonable problem (S/C further from the sun) and partly due to other operations. The temperature stabilized and no problems ensued. In September one of four battery coulometers failed. These are not required for normal operations. On 10/28 the undervoltage/overcurrent trip circuit caused all non-essential equipment to go off. This occurred during a period when the spacecraft was not being monitored by the control center and the spacecraft ws in this condition for 27 hours. As a result, the battery charge went to a high level for a long period of time and the battery temperature reached 48°C. Surprisingly no permanent damage to the battery resulted. The cause of this anomaly is not known.

DE-1 (Dynamic Explorer)

This spacecraft has operated throughout the year without any anomalies. It supported different science programs during the year and in August it attained 6 years in orbit. This is in spite of continuing low power periods and curtailment of operations to prevent over-temperature on the tape recorder.

ERBS (Earth Radiation Budget Satellite)

This spacecraft has continued to perform very well this year - all its scientific objectives were fulfilled. The number of hits (bit-flips) in spacecraft memory was considerably reduced this year. However, a greater percentage of the hits that did occur affected the normal memory rather than block memory. In March this caused an operational code to change to a valid "pitch S/C 180° command". Luckily this was found and corrected before it executed. Another memory hit in June changed a command resulting in the loss of a SAGE data event.

Since the loss of the X-gyro in IRU-1 in August 1986 work has been underway to develop a method of performing the yaw turns on the spacecraft without the use of some or all gyros in an IRU; eventually other gyros will wear out. A Ball Aerospace-developed "no X-gyro " method of performing a yaw turn was utilized for one of the regularly scheduled yaw turns on July *2*. Unfortunately, there was a command error in this procedure wlich caused the roll thruster to burn continuously for 13 minutes before it was stopped by ground command. A complex spacecraft motion quickly developed and spacecraft rates reached 2 degrees per second about the roll axis, and lesser rates about pitch and yaw. Battery power started to drop due to limited solar array illumination and reached 55% depth of discharge. Eventually spacecraft attitude was stabilized and the spacecraft was put into the reacquisition mode in the Magnetic Control System. This was the first time that this mode had ever been used. It took 4 hours but the spacecraft righted itself. This put the sun on the solar array and the batteries charged up to normal. This entire emergency lasted 14 hours. No damage was done and the spacecraft has been operating normally ever since. The next day a normal spacecraft yaw maneuver, using the gyros, was successfully performed. No "new" procedures for performing spacecraft yaw turns have been tried since.

In late October the Y-gyro of IRU-2 began exhibiting high noise and in December the X-gyro (IRU-2) also started to get noisy. These are the same symptoms that the X-gyro of IRU-1 exhibited some 6 months before it failed.

GOES (Geostationary Operational Environmental Satellite)

GOES-2: This spacecraft served as the "CENTRAL" operational spacecraft at 113°W providing CENTRAL WEFAX service until May 14, then standby for the rest of the year. (VISSR is inoperable, power subsystem is degraded, and the SEM was not turned on, although it is operational .)

GOES-3: This spacecraft served as the "WEST" spacecraft at 135°W until April 28, 1986, providing WEFAX and WEST DCS support. The spacecraft was then configured to standby and moved to 129°W for the rest of the year. (VISSR is inoperable, power system is degraded, and the SEM was not used, although operational.)

GOES-4: This spacecraft was used to provide ESA with DCS service during The-entire year at 43°W. The VISSR/VAS is inoperable, the SEM is degraded and was not used operationally, and the Data Collection Platform Report (DCPR) redundant Transmitter-2 was used for DCS operations until it failed on November 6. Although DCPR Transmitter-1 had a failure in early 1986, it was selected, worked for a short time, and then went back into its failure mode (150 Hz jitter on carrier) limiting its usefulness. North-South station-keeping is not being done because of low RCS fuel supply.

GOES-5: This spacecraft wes operated as the "EAST" spacecraft at 75°W providing WEFAX, East DCS, SEM support and transponding GOES-6 stretched VISSR data to users until March 25 when it was replaced by GOES-7. In April the spacecraft was put in a standby mode (only telemetry transmitter on)

and in mid-May it was moved to 107°W to be the GOES "CENTRAL" spacecraft and provide WEFAX service and back-up DCS support. (VISSR/VAS is inoperable and SEM is semi-operational due to degraded and failed channels.)

GOES-6: At the beginning of this year, GOES-6 was the only GOES with imaging capability. It was located at 108° W, the assigned Winter season position. After the GOES-7 launch in late February, and after GOES-7 became operational as the "EAST" spacecraft, GOES-6 was repositioned to 135° W longitude, arriving April 29, where it became the "WEST" spacecraft. NOAA then had a two GOES imaging system for the first time since 7/30/84, when GOES-5 VAS failed. In early June the VAS redundant encoder, at lamp voltage step 3, started to exhibit symptoms that indicated the lamp voltage would have to be stepped up. On July 10 the lamp voltage was increased to step 4. On October 5 this encoder lamp failed and the last encoder lamp (primary encoder) was commanded on and put at voltage step 2. On October 20 VAS operations resumed 24-hours per day marking the first time two spacecraft were providing simultaneous VAS products. The SEM is operational with the EPS E-1 channel degraded due to detector radiation damage.

GOES-7: GOES-H was launched on February 26, and by March 5 it was on station for checkout at 81.5° W. After a speedy, successful checkout, GOES-7 was repositioned to 75° W, turned over to NOAA, and became the "EAST" operational spacecraft March 25, providing Mode A VISSR images, DCS, WEFAX and SEM. Some minor anomalies occurred during this checkout period: On March 4 the 2 High Energy Proton & Alpha Detector (HEPAD) data channels of the SEM Instrument read zero continuously. The cause seems to be that the triple coincidence gate, while functioning normally with calibration data, apparently does not recognize true particle events. The problem may correct itself so the HEPAD will be left on. During the checkout of the VAS multispectral imaging mode, a 6 Hz noise pattern was detected on some of the IR channels (1, *2,* & 9) on March 17. It was determined that this was caused by the excessive settling time of the filter wheel; this is no problem to operations. On May 4 full time Mode AAA VAS operations commenced and continued for the rest of the year. On July 16 VAS Visible Channel 5 had an electronics failure that caused gain steps 1 and 2 to be in constant saturation. Tests revealed gain steps 3 and 4 were still valid and the ground system normalization could handle channel 5 operating at gain step 3. On September 14 VAS visible channel 5 gain increased from step 3 to step 4 uncommanded. This happened two more times in September. These "phantom" commands have not been seen since GOES-5 VAS failed. These gains were reset by ground command. The operational lifetime of this spacecraft's VAS should be greatly increased because of the modified scan drive units which incorporate new lamps and more powrful drive motors. No scan line errors have been detected in 9 months of operation.

ISEE-1 (International Sun-Earth Explorer)

No anomalies were reported on this spacecraft in 1987 and, in the early part of the year, operations continued as reported in previous years. Since it was known that this spacecraft (and ISEE-2) was going to re-enter the atmosphere late in the year, requests were sent out for proposals to perform end-of-life tests. A few end-of-life tests were performed during the 2 weeks preceeding re-entry which occurred on September 26 over North-East Brazil. (For further information see "ISEE 1 and 2 End-of-Life Report" dated February 1988 prepared by Bendix Field Engineering Corp. for NASA-GSFC.) Some ground observers (Brazilians) did see re-entry; both ISEE-1 and ISEE-2 re-entered sequentially.

ICE (International Cometary Explorer) (formerly ISEE-3)

This 9-year old spacecraft continued to operate successfully throughout the year without any reported anomalies. In March, for instance, the Anderson Instrument (X-rays, Protons & Electrons) was pointed toward the recent supernova to determine if there was any X-ray emissions that could be measured by this sensor.

IUE (International Ultraviolet Explorer)

This spacecraft continued to supply excellent science in ultraviolet astronomy. The spacecraft is, however, showing its age. While the batteries are still able to carry the spacecraft through the semiannual shadow seasons, they have shown some indications of degradation. Also, a backup attitude sensor, the Panoramic Attitude Sensor, was found to be inoperable during tests in April. Since this instrument was no longer used, its demise had no impact on operations. Starting in February, IUE spent a considerable amount of time observing the new supernova SN1987A. The IUE observations in both the ultraviolet and the visible spectrums made significant contributions to the study of this rare astronomical phenomena. Throughout the year work continued on a "1-gyro" attitude control system for controlling the spacecraft in the event another gyro fails. This work entails spacecraft software development, ground system testing, as well as spacecraft engineering tests. All work in this area has progressed smoothly.

Landsat-4

Two SOAR'S, one from 1985 and one from 1986, got lost in the pipeline and were finally received in early 1988. One of these vas a minor anomaly that occurred in April, 1985. A component in ESA #2 (Earth Sensor Assembly) failed and necesitated switching to ESA #1. In April 1986, a probable part failure in the MSS Instrument caused loss of the start-of-scan pulse. This was countered by switching to a redundant unit. These old anomalies from years before 1987 are included in the table of anomalies following, but are marked by brackets and a footnote. In June of this year, potentiometer #2 became intermittent and caused OBC trips. This was a minor anomaly and the control center switched to a redundant potentiometer. In the latter part of the year the Thematic Mapper (TM) on this spacecraft was put into operation by curtailing power usage by other parts of the spacecraft. This was necessary because of anomalies in the K-Band system of Landsat-5 that prevented transmission of TM data via TDRS-1. The Multispectral Scanner (MSS) continues to supply data.

Landsat-5

Like Landsat-4, 3 anomalies, written in 1985 and 1986, were not received until early 1988. These anomalies are summarized as follows. In August 1985 the S-Band RF from Transmitter-A became undetectable. As a result it was necessary to switch to another transmitter. In November 1985 potentiometer #2 became intermittent and caused OBC trips which necessitated switching to the redundant potentiometer #1. Then in September 1986 potentiometer #1 experienced the same intermittent problem as #2. This caused a loss in redundancy in this portion of the solar array drive system and complicates operations. Starting in February 1987 there were recurrent trips of the redundant Ku-Band TWTA Helix current protection circuit. This disables the TWTA. Up through September of this year there were some 10 trip outs of this system. (The prime Ku TWTA went down with the same problem in January 1986, at which time the redundant system was activated.) As a result of this recent anomaly the Ku-Band system is out of commission and Thematic Mapper (TM) data can't be transmitted to the ground via the TDRS Spacecraft. The only way TM data can be transmitted is via X-Band directly to a GSTDN station. This is not an acceptable method of standard operations. The TM was powered down and the TM in Landsat-4 was put back in operation in October as mentioned in the Landsat-4 report above. In early October the primary X-Band failed and the redundant X-Band system was activated. The MSS continues to operate satisfactorily.

Nimbus-7

During at least portions of the year this spacecraft continued to provide data from the following instruments: ERB, SAM II, SBUV/TOMS, and SMMR. By June the ERB Instrument had been turned off to make more power available to the other instruments. The SAM II is operated only at the North and South Poles because of a periodic shading problem. Early in the year (April) the SBUV had more and more out-of-sync chopper motor problems and in May these "drop-outs" rose to 100 %. The Ozone Processing Team (OPT) cannot determine the degree of validity of this "sync problem" data. The TOMS behaves fairly well but there was a greater number of drop-outs occurring before the mid-year. This instrument has been supplying important Antarctic ozone hole data. In August it was noticed that the Rate Measuring Package (RMP) gyro sees a larger amount of noise when the SMMR scan is on, (this noise has been gradually increasing since September 1986,) so late in the month it was decided to run the SMMR only in the non-scan mode. Other minor anomalies occurred during the year: in July the solar array probably lost some cells as there was a 0.1 amp drop in output; the tape recorders experienced some intermittent noisy areas on the tape; in late November the THIR Scanner ceased rotating. The THIR had not been used since 2/86. On 10/24/87 the spacecraft attained 9 years in orbit.

NOAA-6

This spacecraft was in standby status from the beginning of the year until 3/31/87 at which time it was turned off (de-activitated.)

NOAA-9

On January 20 the ERBE-Scanner Instrument became in-operative due to an internal clock signal loss. In early March the MSU (Microwave Sounding Unit) experienced a Channel 2 oscillator failure. This is a substantial failure and no corrective action is possible. This failure prompted NOAA to call up NOAA-H for launch late in 1987. Due to a variety of problems and delays NOAA-H has not been launched as of August 1988. (It is presently scheduled for launch on September 24, 1988.) In May the MSU Channel 3 space data counts went to zero indicating a probable part failure. The AVHRR had minor problems early in the year with sync delta word fluctuations and noise in Channel 3. On June 17 the Search and Rescue (SAR) Transmitter-B stopped generating an RF signal. The redundant unit (A) was placed in operation. Significant Power Subsystem problems cropped up with loss of solar array shunts and Battery-2 overcharge. These problems are being addressed by using the stored command table to control battery charge. Other spacecraft operations have not been affected. The NOAA, due to the delay in launching NOAA-H, has developed new algorithms to combine MSU scenes from NOAA-9 and NOAA-10 spacecraft to get adequate data to meet their requirements.

NOAA-10

This spacecraft continued to operate satisfactorily throughout the year with only minor anomalies that had a negligible effect on the mission. In early February the ERBE-Scanner experienced some problems in elevation movement which was very similar to anomalies seen on the ERBE-Scanners on the ERBS and NOAA-9 spacecraft. Some anomalies involving the Skew Gyro related to change in rate output and drift characteristics occurred during the year. This Gyro is not normally in use. In October some gyro self tests helped the situation dramatically so the Gyro can now be used for backup. In May the ERBE-Non-Scanner solar monitor shutter stuck in the open position. This has not affected the instrument's operation. On September 17 NOAA-10 had been in orbit 1 year.

SMM (Solar Maximum Mission)

In January a check was made to determine if Coronagraph/Polarimeter (C/P) data could be sent on main data stream, bypassing the failed Tape Recorder-C; it can. In February the SMM attained 7 years in orbit and in April the spacecraft had the 3rd anniversary since the SMRM (Repair Mission). In the early part of the year the SMM was used for various interesting scientific observations: it observed Cygnus X-1, a black hole; and periodically was rolled some 20° to observe the Supernova (SN1987A.) The Sun has become much more active through the year, approaching another Solar Maximum. There were many high intensity solar flares in November that the spacecraft successfully observed. In August there was a hard failure in the power supply of the Fixed Head Star Tracker No. 2 (FHST #2). Operations continued unaffected with the remaining FHST. Therefore, in general, the SMM continued to obtain much valuable scientific data including the viewing of astronomical bodies it was never intended to observe. Early planning has started to devise ways of continuing the mission beyond the time when the spacecraft would re-enter the atmosphere; currently estimated to be between 1989 and 1992. This would entail using the STS Orbiter to rendezvous with the SMM and give it a boost to a higher orbit.

TDRS-1 (Tracking and Data Relay Satellite)

This satellite continued to serve as still the only TDRS in orbit. In June the polarization switch stuck in the Right Hand Circular Polarization (RHCP) position. Ground commands did not work in trying to switch to the LHCP position. In early July, with repeated attempts, the switch finally switched to LHCP. In August there were more instances of this switch sticking. Also in August a heater circuit opened in the SSA-1F primary TWTA and then there was a 3 dB poker degradation in SSA-IF when configured to the redundant SSA-2E TWTA. In late September, due to problems, the SA-1 (Single Access) service was available for "receive" only. In November the SSA-1F (with redundant TWTA) was declared usable; the Prime TWTA, however is no good.

Anomaly Data: Classification and Description

In the table of anomalies the following information is provided:

1. Index -- This is a chronological enumeration of the anomalies, beginning at launch. Numbers lower than the first number used in this report will be found in earlier reports of the series.

2. Date -- This is the date of occurrence of the anomaly, and in parentheses the number of days since launch is given, counting launch day as one.

3. Subsystem -- For the purposes of this data base, the spacecraft is divided into 9 subsystems. These are:

1. Attitude Control and Stabilization (ACS)
2. Power
3. Propulsion
4. Structure
5. Telemetry and Data Handling (TLM & DH)
6. Thermal
7. Timing, Control and Command (TC & C)
8. Instrument (payload)
9. Other (name to be entered)

4. Criticality -- This describes the impact of the anomaly on the mission, according to the following schedule:

1. Negligible	(O - 5% loss)
2. Non-negligible but small (Minor)	(5 - 33%)
3. 1/3 - 2/3 Mission Loss (Substantial)	(33 - 66%)
4. 2/3 to Nearly Total Loss (Major)	(66 - 95%)
5. Essentially Total Loss (Catastrophic)	(95 - 100%)

5. Description -- A brief description of the anomaly and its probable cause, if known.

6. Effect/Action -- The effect of the anomaly on the mission and corrective action, either for this mission or future missions, if any and if known.

7. Reference -- The number on the SOAR, TOAR, or GAR (if any) covering this particular incident.

Anomalies are also classified in various ways for the purpose of statistical analysis. SOAR calls for the following classifications:

ITEM	CODE	DESCRIPTION
Impact:	1	Spacecraft failed
	2	Subsystem or instrument failed
	3	Component failed
	4	Assembly failed
	5	Part failed
	6	Subsystem or instrument degraded
	7	Indeterminate
	8	Loss of redundancy
	9	None
Failure Category:	1	Design problem
	2	Workmanship problem
	3	Part problem.
	4	Environmental problem
	5	Other (w/explanation)
	6	Unknown
Type of Anomaly:	1	Systematic (would occur if identical equipment were operated under identical circumstances)
	2	Random
	3	Wearout (a special case of systematic)
	4	Indeterminate
	5	Intermittent

These classifications for the 1987 anomalies are given in Table I.

Using the data in Table 1, the 43 "1987 anomalies" can be summarized as follows:

Type of Anomaly	No. of Anomalies
Systematic	1
Random	0
Wearout	2
Indeterminate	40
Intermittent	0

Criticality	No. of Anomalies
Negligible	16
Minor	26
1/3 to 2/3 Mission Loss	1
2/3 to Nearly Total Loss	0
Total Loss	0

If the Negligible and Minor criticality categories are eliminated, there was only one serious anomaly (1/3 to 2/3 Loss) that occurred during the year. This is the same as 1986 in which there was only one such

anomaly. This serious anomaly, Ioss of most of the usefulness of the MSU (Microwave Sounding Unit) on NOAA-9 involved serious degradation of an instrument and caused NOAA (the Agency) to call up the launch of NOAA-H. The Failure Category is probably "Part Problem" and the Anomaly Type is probably "Random."

TABLE I

CLASSIFICATION OF 1987 ANOMALIES

Spacecraft	A	B	C	D	E	F	G	
AMPTE/CCE	9	*2*	*2*	7	-	6	4	
ERBS	10	1	*2*	6	-	5	3	
GOES-7	1	5	1	7	-	6	4	
	2	5	1	7	-	6	4	
	3	5	1	9	-	5	1	
	4	7	1	9	-	6	4	
	5	5	1	9	-	6	4	
	6	8	2	6	-	6	4	
	7	8	*2*	6	-	6	4	
	8	7	2	6	-	6	4	
IUE	31	1	1	3	-	6	4	
LANDSAT-4	[30	1	2	3	Y	6	4]	<< 1985 Anomaly
	[31	8	1	5	Y	3	41	<< 1986 Anomaly
	32	2	*2*	5	Y	3	4	
LANDSAT-5	[5	5	*2*	3	-	6	4]	<< 1985 Anomaly
	[6	2	*2*	5	-	3	4]	<< 1985 Anomaly
	[7	*2*	*2*	5	-	3	4]	<< 1986 Anomaly
	8	5	*2*	3	-	6	4	
NIMBUS-7	43	8	*2*	7	-	6	4	
	44	8	2	7	-	6	4	
	45	5	*2*	9	-	6	4	
	46	*2*	2	6	-	5	3	
	47	8	2	7	-	6	4	
	48	8	*2*	6	-	6	4	
	49	5	2	9	-	6	4	
	50	5	*2*	9	-	6	4	
	51	8	1	4	-	6	4	
	52	1	1	9	-	6	4	
NOAA-9	21	8	*2*	6	-	6	4	
	22	8	2	2	-	6	4	
	23	8	2	9	-	6	4	
	24	8	3	6	-	6	4	A = Index
	25	8	2	9	-	6	4	
	26	8	2	5	-	5	4	B = Subsystem
	27	8	2	3	-	6	4	
	28	8	1	9	-	6	4	C = Criticality (Mission Effect)
	29	2	1	9	-	6	4	
	30	2	1	9	-	6	4	D = Impact
NOAA-10	8	1	1	9	-	6	4	
	9	8	1	9	-	6	4	E = Loss of Redundancy
	10	8	1	6	-	5	4	
SMM	49	1	*2*	3	Y	6	4	F = Failure Category
TDRS-1	46	*2*	1	7	-	6	4	
	47	8	*2*	7	-	6	4	G = Type of Anomaly
	48	8	*2*	6	-	6	4	
	49	8	*2*	*6*	-	6	4	
	50	1	1	1	-	6	4	
	51	8	2	7	-	6	4	

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				AMPTE/CCE		
9	10/28/87 (1168)	POWER	2	Undervoltage/overcurrent trip occurred when S/C not being monitored. Battery hi-charged & temp. increased	Minor/trip re-set	A00907
				DE-1		
				NO ANOMALIES REPORTED IN 1987		
				ERBS		
10	10/26/87 (1116)	ACS	2	Y-gyro of IRU-2 got very noisy. Doesn't effect operation	Minor/None	A00906
				GOES-4, -5, -6		
				NO ANOMALIES REPORTED IN 1987		
				GOES-7		
1	2/26/87 (1)	TLM & DH	1	Aft bearing temperature telemetry word failed full-scale up	Negligible	103
2	2/26/87 (1)	TLM & DH	1	A2 thruster temperature telemetry word is erratic	Negligible	104
3	2/26/87 (1)	TLM & DH	1	R3/R4 thruster temperature telemetry words are reversed	Negligible/Mod. NOAA data base	105
4	2/26/87 (1)	TC & C	1	Spin axis misaligned 0.4° relative to S/C geometric axis	Negligible/ None	106
5	2/26/87 (1)	TLM & DH	1	Doublet pulse on EV channel when CMD decoder cleared	Negligible	110

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
6	3/4/87 (7)	INST-SEM	2	SEM Instrument IIEPAD data channels (2) read zero continuously	Minor/	107
7	3/17/87 (20)	INST-VAS	2	VAS images in bands I., 2 and 9 exhibit noise	Minor/	108
8	3/19/87 (22)	TC & C	2	DCE I intermittent stability	Minor/	109
				ISEE-1, -3 (ICE)		
				NO ANOMALIES REPORTED IN 1987		
				IUE		
31	4/20/87 (3371)	ACS	1	Component failed in Attitude Sensor #2	Negligible/ None	A01117
				LANDSAT-4		
30	[4/17/851* (1006)	ACS	2	Component failure in Earth Sensor Assembly # 2 (ESA)	Minor/Switch to ESA # 1	A00799
31	[4/25/86]* (1379)	INST-MSS	1	Probable part failure caused loss of start-of-scan pulse	Negligible/ to redundant	A00805
32	6/22/87 (1802)	POWER	2	Intermittent potentiometer #2 caused OBC trips	Negligible/ to redundant	A00810
				LANDSAT-5		
5	[8/13/851* (530)	TLM & DH	2	Xmtr-A S-Band RF is now undetectable	Minor/use other xintr	A00801
6	[11/10/851* (619)	POWER	2	Intermittent potentiometer # 2 caused OBC trips	Minor/switch to redundant	A00802

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
7	[9/22/861* (935)	POWER	2	Intermittent potentiometer # 1 (See Index 6, above)	Loss of redundancy	A00807
8	2/5/87 (1071)	TLM & DH	2	Recurrent trips of redundant Ku-band TWTA Helix current protection circuit	TWTA disabled	A00809
				NIMBUS-7		
43	2/4/87 (3025)	INST-ERB	2	Solar channel ass'y did not step when commanded	2nd command worked	A01128
44	2/13/87 (3034)	INST-SBUV	2	Non-sync condition of chopper and increase in current	Minor/info degraded	A01129
45	3/30/87 (3079)	TLM & DH	2	Intermittent noisy area on GSTR-3, Went away after re-record cycle	Minor/record over noise	A01130
46	7/11/87 (3182)	POWER	2	0.1 amp drop in solar array output, possible loss of cell(s) 0.2	Minor/none	A01131
47	7/24/87 (3195)	INST-SMMR	2	RMP sees noise when SMMR scan on. Gradual increase since 9/86	Minor/no action	A01133
48	8/20/87 (3222)	INST-SMMR	2	At scan turnoff there is oscillation around Nadir	Minor	A01134
49	11/6/87 (3300)	TLM & DH	2	Noisy area on tape of TR-2 Eventually disappeared	Minor/none	A01136
50	11/25/87 (3319)	TLM & DH	2	Noisy area on tape of TR-3 noise disappeared later	Minor/none	A01198
51	11/30/87 (3324)	INST-THIR	1	Scanner ceased rotating. THIR had not been active since 2/86	Negligible	A01200
52	12/1/87 (3325)	ACS	1	Glitch on rear scanner produced false error indication	Negligible/ none	A01199

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				NOAA-6		
				NO ANOMALIES REPORTED IN 1987 (SPACECRAFT DEACTIVATED IN MARCH 1987)		
				NOAA-9		
21	1/3/87 (752)	INST-AVHRR	2	Sync delta count jumped up and became erratic	Minor	259
22	1/20/87 (769)	INST-ERBE-S	2	All digital A data from ERBE Scanner went to zero due to clock signal loss	Minor	260
23	1/21/87 (770)	INST-ERBE-NS	2	Sun interference at the azimuth sensor input caused counter to reset several times & read erroneously	Minor	262
24	3/8/87 (816)	INST-MSU	3	Channel 2 oscillator failure, data anomalous	Substantial/ No action poss.	261
25	4/8/87 (847)	INST-AVHRR	2	AVHRR began re-syncing mode in a random manner	Minor/put in hi-pwr mode	264
26	5/7/87 (876)	INST-MSU	2	Channel 3, space data, indicates zero: probable part failure	Minor/none	267
27	6/17/87 (917)	INST-SARR	2	Xmtr-B stopped generating an RF signal	Minor/use redundant xmtr	268
28	9/5/87 (997)	INST-HIRS	1	Channel #1 NE delta N noise level temporarily increased	Negligible/No effect on data	269
29	9/18/87 (1010)	POWER	1	Partial shunt drive voltage exceeds limit	Negligible/condition stable	270

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
30	11/18/87 (1071)	POWER	1	Batt #2 terminal voltage decreased 200 mv - caused overchg & hi-temp.	Neg./has stabilized acceptably	271
				NOAA-10		
8	3/4/87 (168)	ACS	1	Skew gyro mean rate output changed over 10 day period & then returned to normal	No attitude perturbations	263
9	4/9/87 (204)	INST-MSU	1	Several line count positions intermittently became abnormal	None/none	265
10	4/29/87 (224)	INST-ERBE-NS	1	Solar monitor shutter stuck in open position	Negligible	266
				SMM		
49	8/19/87 (2743)	ACS	2	Star tracker #2 power supply failure-data no good	Minor/none	A01005
				TDRS-1		
46	1/21/87 (1388)	POWER	1	Temporary stopping of solar array clocking	Negligible	A01196
47	6/19/87 (1537)	INST-DATA RELAY	2	Couldn't switch from RHCP to LHCP-switch stuck. Switched ok later	Minor/Modify operations	A01197
48	8/8/87 (1587)	INST-DATA RELAY	2	Open heater circuit in SSA-1F primary TWTA	Minor	A01208
49	8/11/87 (1590)	INST-DATA RELAY	2	3 dB power degradation in SSA-1F when configured to redundant SSA-2E TWTA	Minor	A01195

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
50	10/8/87 (1648)	ACS	1	Unexplained attitude divergence occurred but was self-correcting in 20 min.	Negligible	A01209
51	11/26/87 (1697)	INST-SA 1 & 2	2	Signal composite downlink degradation of 4 dB during SA 1 & 2 return signal testing	Minor/further tests will be run	A01210

* Not received until

APPENDIX A

SPACECRAFT LIFETIME DATA

Note: In the following table, the term "useful life" refers to the time during which the major mission objectives were met. Active life is the total lifetime during which the satellite remained in service. A blank space means the information was not available. Data is through 1987; see text for update.

SPACECRAFT LIFETIMES

SPACECRAFT	LAUNCH DATE	DESIGN LIFE (YRS)	USEFUL LIFE (YRS)	ACTIVE LIFE (YRS)	REMARKS
TIROS	4/1/60	0.25	.24	.24	TV system useful for 77 days
Explorer VIII (S-30)	11/3/60	0.25	.15	.15	Last transmission 12/28/60
TIROS-II	11/23/60		.63	1.03	TV data useful to 7/12/61
Explorer XI (S-15)	4/27/61		.61	.61	Last transmission 12/7/61
TIROS-III	7/12/61	.25	.40	.63	TV data useful to 12/4/61. Lost tape recorders.
Explorer XII (S-3)	8/15/61	1.0	.31	.31	Transmission ceased abruptly
TIROS-IV	2/8/62	0.25	.36	.44	TV useful to 6/9/62. Lost tape recorders.
OSO-I	3/7/62	0.5	1.40	1.40	Lost tape recorder @ 2 mos. starfish incident degraded power system.
Ariel-I (S-51)	4/26/62	1.0	0.88		Degraded by starfish incident of 7/9/62.
TIROS-V	6/19/62	0.5	0.88	0.88	TV useful to 5/4/63. Camera filaments failed.
TIROS-VI	9/18/62	0.5	1.06	1.06	TV useful to 10/11/63. Filaments and focus out.
Explorer XIV (S-3a)	10/2/62		0.85	1.20	Last transmission 2/17/64
Explorer XV (S-3b)	10/27/62	0.17	0.26	0.55	Despin system failed. Last transmission 5/19/63.
Relay I	12/13/62	2.0	2.53	2.53	
Syncom I	2/14/63	2.0	0	0	Lost power, mission failure.
Explorer XVII (S-6)	4/3/63	0.25	.27	.27	Batteries degraded. No solar array.
TIROS-VII	6/19/63	0.5	4.33	4.96	Deactivated. Camera focus out 12/65.
Syncom II	7/26/63	2.0	N/A	N/A	
IMP-A	11/26/63	1.0	0.82		
TIROS-VIII	12/21/63	0.5	3.53	3.53	Deactivated.
Relay-II	1/21/64	1.0	1.68	3.50	
Ariel-II (S-52)	3/27/64	1.0	0.53		Had spin rate and attitude control problems.
Syncom III	8/19/64	3.0	N/A	N/A	
Explorer XX (S-48)	8/25/64		1.60	1.60	Based on last transmission 3/30/66.
Nimbus-I	8/28/64	0.5	0.07	0.07	Solar array drive failed.
OGO-1(A)	9/4/64	1.0	5.23	5.23	Mission failure. 3-axis stabilization not achieved.
IMP-B	10/3/64	1.0	0.50	1.25	Reentered. Placed in wrong orbit.
Explorer XXVI (S-3c)	12/21/64	1.0	2.10	2.10	Last transmission 1/21/67.
TIROS-IX	1/22/65	0.5	2.73	3.4	Deactivated. Camera contrast out 10/66.
OSO-II	2/3/65	0.5	0.75	0.75	Used up control gas.
IMP-1(C)	5/29/65	1.0	1.92	1.92	Reentered.

SPACECRAFT LIFETIMES

SPACECRAFT	LAUNCH DATE	DESIGN LIFE (YRS)	USEFUL LIFE (YRS)	ACTIVE LIFE (YRS)	REMARKS
TIROS-X	7/2/65	1.0	1.16	2.00	Deactivated.
OGO-2(C)	10/14/65	1.0	3.48		Mission failure: Horizon scanners did not maintain earth lock.
ESSA-I	2/3/66	1.0	2.36	2.36	Deactivated.
ESSA-II	2/28/66	1.0	4.64	4.64	Deactivated.
OAO-I	4/8/66	1.0	0	0	Mission failure: Lost power
Nimbus-II	5/16/66	0.5	2.67	2.67	ACS scanner failed.
AE-B	5/25/66	0.5	0.82		Higher than planned orbit. Two sensors did not work.
OGO-3(B)	6/6/66	1.0	2.04	3.5	Boom oscillation problem.
AIMP-2(D)	7/1/66	0.5	4.92		Failed to achieve lunar orbit.
ESSA-III	10/2/66	1.0	2.02	2.02	Deactivated. Cameras failed
ATS-I	12/6/66	3.0		ACTIVE	Gas expended. Limited service
ESSA-IV	1/26/67	1.0	0.41	1.27	Deactivated. One camera failed, one degraded.
OSO-III	3/8/67	0.5	3.0	3.0	Tape recorder failure at 18 mos. ACS controlled manually.
ESSA-V	4/20/67	1.0	2.83	2.83	Deactivated. IR failed, cameras gradually degraded.
IMP-3(F)	5/24/67	1.0	1.95	1.95	Reentered.
AIMP-4(E)	7/19/67		3.50	3.50	Lunar orbit. Subsequent period of intermittent operation.
OGO-4(D)	7/28/67	1.0	2.24	2.75	Thermal bending of antenna caused stabilization control problem.
OSO-IV	10/18/67	0.5	0.90		Tape recorder failure at 6 mos.
ATS-III	11/5/67	3.0		ACTIVE	Instruments no longer in use
ESSA-VI	11/10/67	1.0	2.09	2.09	Deactivated Cameras degraded
OGO-5(E)	3/4/68	1.0	3.60	3.60	Deactivated. Data glut
RAE-A	7/4/68	1.0	4.50	4.50	Deactivated. Data quality had become marginal.
ESSA-VII	8/16/68	1.0	0.92	1.56	Deactivated. Early camera and tape recorder failures
OAO-II	12/7/68	1.0	4.20	4.20	Prime instrument (WEP) failed.
ESSA-VIII	12/15/68	1.0	4.95	6.75	Deactivated. Camera problems
OSO-V	1/22/69	0.5	3.9	3.9	
ESSA-IX	2/26/69		4.1	4.1	Deactivated. Standby after 4/71.
Nimbus-3	4/19/69	0.5	2.67		ACS Scanner failed 1/72.
OGO-6 (F)	6/5/69	1.0	2.06	2.25	Deactivated. Data glut

SPACECRAFT LIFETIMES

SPACECRAFT	LAUNCH DATE	DESIGN LIFE (YRS)	USEFUL LIFE (YRS)	ACTIVE LIFE (YRS)	REMARKS
IMP-5(G)	6/21/69		3.51	3.51	Reentered.
OSO-VI	8/9/69	0.5	3.30	3.30	
ATS V	8/12/69	3.0	14.84	14.84	Mission officially unsuccessful: Stabilization not achieved. Deorbited 3/20/84
TIROS-M	1/23/70	1.0	1.40	1.40	Momentum wheel assembly failed.
Nimbus-4	4/8/70	1.0	10.00	10.00	Deactivated.
NOAA-1 (ITOS-A)	12/11/70	1.0	.56	0.75	Deactivated. Momentum wheel assembly problems.
SAS-A	12/12/70	0.5	4.00	4.00	Transmitter failure terminated mission.
IMP-6(I)	3/13/71	1.0	3.56	3.56	Reentered.
OSO-VII	9/29/71	0.5	3.17	3.17	Reentered due to bad orbit
SSS-A	11/15/71	1.0	2.87	2.87	Deactivated. Battery unusable, as expected after 1 year.
Landsat-1 (ERTS-A)	7/23/72	1.0	5.58	5.58	Deactivated: Funding withdrawn
OAO-C	8/21/72	1.0	8.50	8.50	Deactivated: Funding withdrawn
IMP-7(H)	9/22/72	2.0	6.10	6.10	Power system failed.
NOAA-2 (ITOS-D)	10/15/72	1.0	2.25	2.40	Standby after 3/74. Some experiments failed.
SAS-B	11/16/72	0.5	.54	.54	Experiment low voltage power supply failed.
Nimbus-5	12/12/72	1.0	10.30	10.30	Deactivated 3/31/83. Second HDRSS failed 7/27/82.
RAE-B	6/10/73	1.0	3.75	3.75	Deactivated. Mission objectives achieved.
IMP-8(J)	10/25/73	2.0	ACTIVE	ACTIVE	All instruments operating.
NOAA-3 (ITOS-F)	11/6/73	1.0	2.84	2.84	Deactivated. Radiometer, VTPR, VHRR out
AE-C	12/16/73	1.0	5.00	5.00	Reentered.
SMS-1	5/17/74	2.0	1.60	6.70	Standby after 1/76. Deactivated 1/31/81.
ATS-6(F)	5/30/74	5.0	5.17	5.17	Deactivated.
NOAA-4 (ITOS-G)	11/15/74	1.0	4.00	4.00	Deactivated. Radiometer, VHRR's out.
Landsat-2	1/22/75	1.0	8.51	8.51	Yaw flywheel stopped 11/79, recovered 5/80. Permanently turned off July 27, 1983.
SMS-2(B)	2/6/75	2.0	6.50	7.50	Second encoder failed on 8/5/81.
SAS-C	5/7/75	1.0	4.92	4.92	Reentered.
Nimbus-6(F)	6/12/75	1.0	7.18	8.28	Yaw flywheel failed 8/14/82.
OSO-8(I)	6/21/75	1.0	3.40	3.40	Funding withdrawn
AE-D	10/6/75	1.0	0.42	0.42	Shorted diode in power supply electronics.
GOES-1(A)	10/16/75	3.0	9.3	9.4	VISSR failed 2/85

SPACECRAFT LIFETIMES

SPACECRAFT	LAUNCH DATE	DESIGN LIFE (YRS)	USEFUL LIFE (YRS)	ACTIVE LIFE (YRS)	REMARKS
AE-E	11/20/75	1.0	5.56	5.56	Reentered 6/10/81
NOAA-5 (ITOS-H)	7/29/76	1.0	2.96	2.96	Failed 7/79
GOES-2 (B)	6/16/77	3.0	1.55	1.55	VISSR failed 1/79
ISEE-1(A)	10/22/77	2.0	9.93	9.93	S/C re-entered 9/26/87
IUE	1/26/78	3.0	ACTIVE	ACTIVE	Fully operational. Some problems w/ computer "HALTS"
Landsat-3(C)	3/5/78	3.0	5.07	5.51	Problems with MSS instrument
AEM-A (HCMM)	4/26/78	1.0	2.40	2.40	Deactivated. Battery degraded 9/14/80.
GOES-3(C)	6/16/78	3.0	2.21	ACTIVE	VISSR degraded 9/80. Failed 5/6/81.
ISEE-3(C) [ICE]	8/12/78	2.0	ACTIVE	ACTIVE	Some instrument losses.
TIROS-N	10/13/78	2.0	2.38	2.38	ACS failed 2/27/81.
Nimbus-7(G)	10/24/78	1.0	ACTIVE	ACTIVE	Solar array power and some instruments degraded.
AEM-B (SAGE)	2/18/79	1.0	2.75	2.75	Battery degraded. Failed 11/18/81.
NOAA-6(A)	6/27/79	2.0	7.39	7.75	S/C turned off 3/31/87
Magsat	10/30/79	0.4	.61	.61	Reentered as planned 6/11/80
SMM*	2/14/80	2.0	[0.83] +[5.62]	ACTIVE	Lost fine pointing control 12/12/80, then repaired.
GOES-4(D)	9/9/80	7.0	2.21	6.66	VAS failed 11/25/82.
GOES-5(E)	5/22/81	7.0	3.19	ACTIVE	VAS failed 7/30/84.
NOAA-7(C)	6/23/81	2.0	3.62	4.92	Failed HIRS, degraded SSU, disabled power system.
DE-1(A)	8/3/81	1.0	ACTIVE	ACTIVE	
DE-2(B)	8/3/81	1.0	1.54	1.54	Reentered as expected 2/19/83.
OSS-1	3/22/82	--	--	--	Shuttle attached payload mission.
Landsat-4(D)	7/16/82	3.0	ACTIVE	ACTIVE	Partial solar array loss.
NOAA-8(E)	3/28/83	2.0	1.25	1.25	Failed 7/1/84. Recovered May 1985. Failed again 1/86.
TDRS-1(A)	4/4/83	**	ACTIVE	ACTIVE	Some loss of capability.
GOES-6(F)	4/28/83	7.0	ACTIVE	ACTIVE	
Landsat-5(D')	3/1/84	3.0	ACTIVE	ACTIVE	K-Band failed; can't send TM data via TDRS-1 (Late '87)
AMPTE/CCE	8/16/84	1.0	ACTIVE	ACTIVE	Some solar array degradation.
ERBS	10/5/84	2.0	ACTIVE	ACTIVE	IRU-1/X-gyro failure
NOAA-9(F)	12/12/84	2.0	3.92	ACTIVE	MSU & ERBE-S failure.
SPARTAN-1	6/20/85	--	--	--	STS attached payload mission

SPACECRAFT LIFETIMES

SPACECRAFT	LAUNCH DATE	DESIGN LIFE (YRS)	USEFUL LIFE (YRS)	ACTIVE LIFE (YRS)	REMARKS
SPOC/HITCHHIKER	1/12/86	--	--	--	STS attached payload mission
NOAA-10(G)	9/17/86	2.0	ACTIVE	ACTIVE	
GOES-7(H)	2/26/87	7.0	ACTIVE	ACTIVE	

* Repaired by crew of shuttle flight 41-C on April 12, 1984.
** Complex warranty provisions call essentially for 10-year service from TDRSS system.